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Comparison of stochastic methods in interpolation and extrapolation of sparse GNSS TEC observations

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GNSS dual-frequency observations provide slant Total Electron Content (TEC) point measurements in Ionosphere Pierce Points (IPPs), assuming single-layer ionosphere approximation. Although GNSS ensures today a predominant part of satellite ionospheric TEC observations, the networks of global permanent GNSS stations are heterogeneous. Therefore, the density of IPPs is substantially various, causing large gaps in the oceanic regions. Altimetry-derived or DORIS-derived TEC doesn't completely solve this problem, due to the small number of the satellites. Thus, the interpolation techniques routinely applied in gridded TEC models creation have the problems coming from the data gaps, and additionally the differences between different modeling techniques are larger in the regions of sparse data.

The limited data resolution determines limited average resolution of TEC models. The models are approximated by a relatively low degrees of the spherical basis functions like e.g. spherical harmonics. These functions are very sensitive to the data gaps, and on the other hand the regions with denser data suffer from the high-frequency cutoff of the signal. Therefore, two challenges occur at the same time in TEC modeling: a better resolution of the regional models or some regions of global models, and the accuracy of different modeling techniques in the areas of data gaps. Stochastic modeling techniques restore full spatial resolution that corresponds to the data resolution, and being based on the data empirical correlation are able to interpolate data gaps optimally in the least-squares sense.

There are variety of stochastic techniques, and even if they are based on the same assumption of least-squares rule, can have different detrending schemes, correlation approximations and parametrization methods. The most interesting testing areas for the assessment of the modeling differences are data gaps and denser data locations. Therefore, three techniques are applied over the selected regions of the mentioned characteristics: simple kriging (SK), often compared to least-squares collocation (LSC) known in geodesy, ordinary kriging (OK) and universal kriging (UK). These methods are parametrized via cross-validation and the created models are also tested in the repeated cross-comparisons over the extremely sparse and dense data. The results reveal differences between LSC, OK and UK in the conditions of data deficiency, and some similarities in the regions of dense, homogeneous observations. The regions of the latter kind are also interesting for the comparisons of the stochastic techniques with spherical harmonics modeling.